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# Numerical simulation for characteristic analysis of vertical axis wind turbine

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## Purpose of Research & Background

### Research Background

Global warming is a global problem.
Reduction of greenhouse gases is necessary.

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The use of renewable energy and decentralized power generation is effective.

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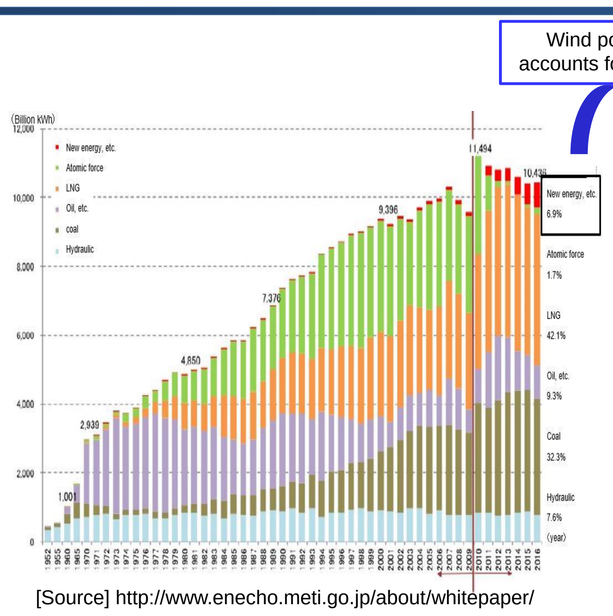
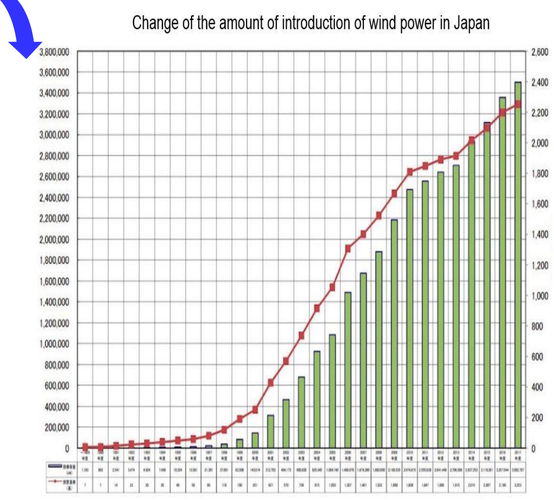
Wind power generation is one of a effective solution.

### Japan's Energy Distribution




[Source] http://www.enecho.meti.go.jp/about/whitepaper/



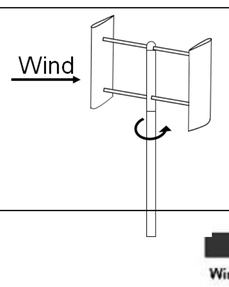
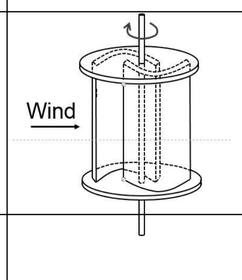
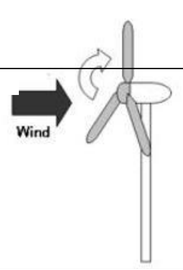
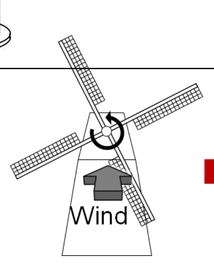

[Source] http://www.nedo.go.jp/library/fuuryoku/index.html

Offshore wind power generation is attracting attention as a new energy source in Japan.

[Source] https://www.mugendai-web.jp/archives/933

## Scope of This Research

### Ford Types of Wind Turbine

| | Lift Type | Drag Type |
|---|---|---|
| **Vertical Axis Type** |   |   |
| **Horizontal Axis Type** |   |   |

Can be placed on the bottom of the wind turbine such as a generator
→Stable

It is necessary to follow the change of the wind direction

Rotate quickly.
→Power generation

High torque
→Ventilation, Pumping, For startup.

### Characteristics of VAWT

**Advantages of Vertical axis type**

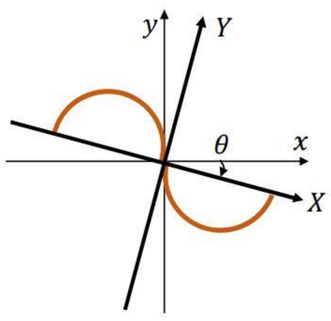
- Simple construction with low cost
- Wind acceptance from any direction for the operation
- Low noise and angular velocity in operation
- Reduced wear on moving parts
- Various rotor configuration options
- High static and dynamic moment

**Purpose of This Work**

The optimum shape of a 2-stage Savonius wind turbine (one of a VAWT) is examined using a simulation technique for fluid phenomena.

## Numerical Method

### Wind Turbine Calculation Formula




$$\frac{\partial U}{\partial X}+\frac{\partial V}{\partial Y}+\frac{\partial W}{\partial Z}=0$$

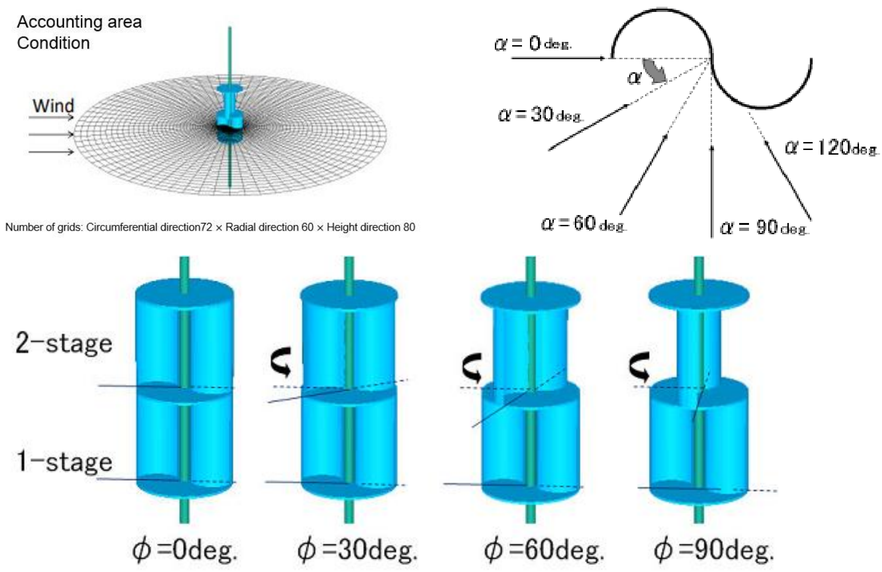
$$\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial X}+V\frac{\partial U}{\partial Y}+W\frac{\partial U}{\partial Z}-\omega^2 X+2\omega V=-\frac{\partial p}{\partial X}+\frac{1}{\mathrm{Re}}\left(\frac{\partial^2 U}{\partial X^2}+\frac{\partial^2 U}{\partial Y^2}+\frac{\partial^2 U}{\partial Z^2}\right)$$

$$\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial X}+V\frac{\partial V}{\partial Y}+W\frac{\partial V}{\partial Z}-\omega^2 Y-2\omega U=-\frac{\partial p}{\partial Y}+\frac{1}{\mathrm{Re}}\left(\frac{\partial^2 V}{\partial X^2}+\frac{\partial^2 V}{\partial Y^2}+\frac{\partial^2 V}{\partial Z^2}\right)$$

$$\frac{\partial W}{\partial t}+U\frac{\partial W}{\partial X}+V\frac{\partial W}{\partial Y}+W\frac{\partial W}{\partial Z}=-\frac{\partial p}{\partial Z}+\frac{1}{\mathrm{Re}}\left(\frac{\partial^2 W}{\partial X^2}+\frac{\partial^2 W}{\partial Y^2}+\frac{\partial^2 W}{\partial Z^2}\right)$$

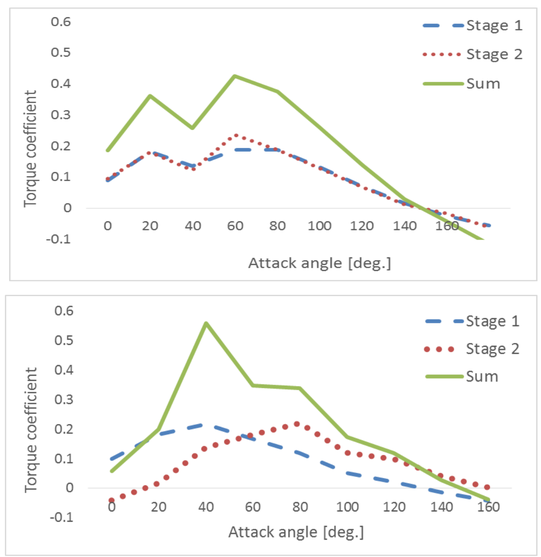
$(X, Y, Z)$ : Position component in rotational coordinate system
$(U, V, W)$ : Velocity component in rotational coordinate system
$p$ : Pressure $t$ : Time $\omega$ : Angular velocity of wind turbine
$\mathrm{Re}$ : Reynolds number based on wind turbine radius and uniform flow $(= 10^5)$

### Condition of Simulation

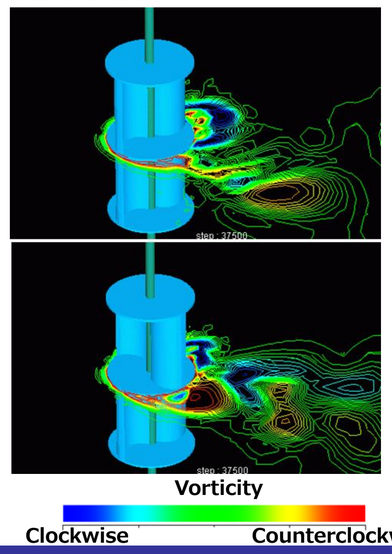



## Simulation Results

### Comparison of Simulation Results




Flow Field




## Summary

The wind turbine has the highest torque coefficient compared to other wind turbines when $\phi$ is 30 degrees. When the torque coefficient is negative, the wind turbine can not be start to rotate. The torque coefficients of Stage 1 and Stage 2 are canceled, and the total torque does not become negative when $\phi$ is more than 60 degrees.

J.V. Akwa, H.A. Vielmo, A. Prisco “A review on the performance of Savonius wind turbines”Renewable and Sustainable Energy Reviews, 16 (5) (2012), pp. 3054-3064